

***Utricularia* (Lentibulariaceae) habitat diversity in Peninsular Malaysia and its implications for conservation**

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ABSTRACT. *Utricularia* is a cosmopolitan carnivorous genus with more than 30 species in Malesia, of which 14 occur in Peninsular Malaysia. *Utricularia* species exhibit a range of habits including free-floating or affixed aquatic, semi-aquatic, terrestrial, lithophytic or epiphytic. In terms of habitat preference, three arbitrary groups are recognised, namely, habitat specialists, habitat generalists, and open and wayside pioneers. This grouping allows information on niches to be interpreted into conservation management measures. One third of the Peninsular Malaysian species are habitat specialists, found either in single localities or in one microhabitat. Among them, *U. furcellata* and *U. scandens* are listed as 'Critically Endangered' for the Red List for Peninsular Malaysia, whereas *U. involvens* and *U. punctata* are 'Vulnerable' and *U. vitellina* is 'Rare'. Four species, *U. caerulea*, *U. gibba*, *U. striatula* and *U. uliginosa*, are found in many sites and microhabitats and are thus considered generalists, with their conservation status varying from 'Vulnerable' to 'Least Concern'. *Utricularia aurea*, *U. bifida* and *U. minutissima* are adaptable pioneers able to co-exist with weeds and they may also be indicators of past disturbance. Two rare species, *U. limosa* and *U. subulata*, have not been relocated recently and their local habitat preferences are uncertain.

Keywords. Conservation, habitat diversity, Peninsular Malaysia, *Utricularia*

Introduction

Utricularia L. (Lentibulariaceae) is a large genus of carnivorous plants, with c. 220 species worldwide and c. 30 species in Malesia (Taylor 1989). It is cosmopolitan, found in all continents from subarctic landscapes to tropical rain forest, at oases in deserts and on oceanic islands (Brummit 2007). To date, 14 species are recorded from Peninsular Malaysia.

The genus has a unique body plan among flowering plants as highlighted by Rutishauser & Isler (2001). *Utricularia* has no true root; the rudimentary anchoring rhizoids lack a root cap. Its stolons have randomly arranged phloem and xylem instead of the collateral vascular bundles typical of angiosperm stems. The foliar organs or leaves arise at the bases of peduncles or along stolons. Leaf laminas of the terrestrial species are often minute, while in the aquatic species they are much dissected. The inflorescences are racemes with indefinite growth, sometimes branched or twining. The minute traps are highly modified, glandular organs arising from the leaves, stolons

or rarely from other parts. These traps function to supplement their nutrient intake by trapping microfauna, microflora and microbes (Richards 2001, Sirova et al. 2009). In Peninsular Malaysia, *Utricularia* is found almost exclusively in nutrient-poor environments with low pH.

Three species of *Utricularia* in Peninsular Malaysia are free-floating aquatics from the section *Utricularia*, that includes *U. aurea* Lour., *U. gibba* L. and *U. punctata* Wall. ex A.DC., of which the latter two also exist as affixed aquatics. Nine species are terrestrials that are sometimes semi-aquatic. They are *U. minutissima* Vahl from section *Meionula*, *U. caerulea* L. from section *Nigrescentes*, *U. limosa* R.Br. from section *Nelipus*, *U. subulata* L. from section *Setiscapella* and *U. bifida* L., *U. involvens* Ridl., *U. scandens* Benj., *U. uliginosa* Vahl and *U. vitellina* Ridl. from section *Oligocista*. There are only two species of minute and rosette lithophytic herbs, namely *U. furcellata* Oliv. and *U. striatula* Sm. from section *Phyllaria*, which at times are terrestrial or epiphytic within the cloud forest or waterfall splash zones.

Authors prior to Ridley gave little mention of the ecology and distribution of *Utricularia* species found in the region. Ridley (1893, 1895, 1901, 1908, 1923), Henderson (1928) and Spare (1941) provided background knowledge on the habitats and commonness of local *Utricularia* but held slightly different opinions on taxonomic delimitation. Taylor's (1977) treatment of the genus in Malesia detailed the distribution and ecology for every taxon, although this was not specific to Peninsular Malaysia. Turner (1995) summarised habitat information provided by Ridley and Taylor in his plant checklist for the Peninsula but did not add new information. Parnell's (2005) account on Thai *Utricularia* provided ecological details on habitat and substrate type, altitudinal range and flowering period, of which eleven of the Peninsular Thailand species also extend into Peninsular Malaysia.

This study was carried out as part of the revision of *Utricularia* for the Flora of Peninsular Malaysia. It aimed to document the range of habitats and niches occupied by various *Utricularia* species, to understand the implications of their distribution ranges and habitat preferences, and to formulate conservation measures based on the assessments of such information. For non-endemic species, the Red List status obtained is only applicable to Peninsular Malaysia.

Materials and methods

General collection was carried out at various wet habitats to obtain materials of the common and widespread species, and specialised fieldtrips were organised to relocate rare species at specific sites. Habitat information including GPS readings, elevation, exposure, substrate type, water depth, pH, associated plants, range of niches occupied and known history of disturbance were recorded for specimens collected in the field. Relevant label information for existing herbarium specimens was databased. In the absence of any habitat records, information was inferred from the Kepong BRAHMS gazetteer database.

Table 1. Criteria for arbitrary habitat-preference groupings.

Habitat-preference group	Number of collection localities	Microhabitat specificity	Tolerance to disturbance
Habitat specialists	1–2	≤ 5 niche subtypes	Pristine / lightly disturbed (by trails etc.)
Habitat generalists	> 3 (≤ 25)	> 5 niche subtypes	Mostly in or near natural vegetations
Open / wayside pioneers	Many (≥ 30)	> 8 niche subtypes	Mostly disturbed (abandoned land)

The lowest and highest spatial range occupied by a species was shown by the elevation data. Latitude and longitude of collection sites were plotted with ArcView to generate the Extent of Occurrence (EOO) and Area of Occupancy (AOO) maps. Three arbitrary habitat-preference groups were established according to criteria listed in Table 1.

Conservation assessment was carried out following the IUCN Red List Categories and Criteria version 3.1 (2001). The assessment was largely specimen based; verified or published records were included when specimen information was lacking. The Taxon Data Information Sheets (TDIS) modified from the IUCN Red List Assessment Questionnaire to suit the requirements for local plants, as recommended by the Malaysia Plant Red List guidebook (Chua & Saw 2006), were then completed for each species. TDIS comprises five parts, i.e., Taxon Attributes, Geographical Range and Demographic Details on Population, Red List Category and Criteria Assessment, Current Conservation Measures for the Taxon and Utilisation.

Habitat preferences and the associated population size data provided the basis for the IUCN Red List criterion A, scoring on population reduction. EOO, AOO and distribution patterns were used to evaluate the Criterion B, scoring on geographical range, which has been designed to identify populations with restricted, declining or fluctuating distributions in the present or near future (IUCN 2010).

Results and discussion

Microhabitat types, biotic and abiotic properties and altitudinal range

In Peninsular Malaysia, *Utricularia* occurs in a range of perpetually or seasonally wet microhabitats—from pristine lowland and montane swamps to fairly disturbed, meso-eutrophic ditches, as detailed in Appendix A. The aquatics usually occupy the open shallow waters; the terrestrials or semi-aquatics grow on multifarious waterlogged or shallowly inundated soils; lithophytic species often grow on rock-faces with dripping water. Some of these habitats are subject to periodic drought, where the annual or ephemeral *Utricularia* populations die out in the dry months. In line with the cost-

benefit model for carnivorous plants (Givnish et al. 1984), the genus generally prefers sunny, moist and low-nutrient habitats with low pH (3–7). Some species are able to tolerate deep shade and eutrophic waters but do not flower under such conditions.

The altitudinal range of the genus extends from the coastal *Typha* reed beds in Pulau Langkawi to the montane sandstone plateau of Gunung Tahan, the highest peak in Peninsular Malaysia at 2187 m. Edaphic conditions and light availability are more crucial in determining the presence or absence of *Utricularia*, rather than altitude. It is not found in mangroves, coastal lagoons, inland salt-licks and hot springs, due to its intolerance for high pH and salinity; nor reservoirs with steeply shelving shores, large swift rivers and concrete waterways which do not provide stable substrate for establishment. The genus is generally absent from tall-forested areas with closed canopies while being fairly common along streams, heaths, swamps, along forest fringes, in forest gaps, trails or other edaphic and biotic vegetation types nestled within the climactic forests, wherever there is adequate sunlight and moisture.

Habitat preferences and conservation status

The habitat specialists are species that are found only in a single locality or one type of microhabitat. One third of species from the Peninsula falls within this group. The habitat generalists consist of plants that are found in many sites and suited to live in many types of wet microhabitat but rarely found in heavily disturbed sites. Common pioneers of open and wet-habitat are adaptable plants that are able to co-exist with weeds and may indicate past disturbance.

The conservation status of a particular species is related to its habitat-preference because this affects its overall distribution and commonness. If the particular locality where a species is found is within a protected area, the conservation status then falls into a much lower category, as listed in Table 2. However, although population decline is perceived as minimal in protected areas for most plants, the type of fringe habitats *Utricularia* favours is often sacrificed in the process of amenity or trail development, or depleted by high-impact or uncontrolled recreational activities. Thus, their survival is not fully guaranteed, especially for the habitat specialist and habitat generalist.

Habitat specialists

Utricularia furcellata (Fig. 1A) is a new record for Peninsular Malaysia (Chew et al. 2011). It is differentiated from the more common *U. striatula* as detailed in Appendix B and Fig. 2A–B. *Utricularia furcellata* grows in a localised population on the montane heath of Gunung Ayam, within Gunung Stong State Park, Kelantan. The species is previously known to grow on moist rocks (1500–2700 m) in North-eastern India and mossy wet tree boles and rocks in lower montane forest (>1700 m) in Northern Thailand. In Kelantan, *U. furcellata* exists as a terrestrial herb on a patch of white-sandy heath within the cloud forest zone inundated with a thin film of water. The site is traversed by a major hiking trail. Up to 2003, the trail was reported to receive an average of more than 2500 climbers (out of 5000 visitors to the area) annually with an increasing trend (Maseri et al. 2006).

Table 2. Conservation status of *Utricularia* species in Peninsular Malaysia in relation to habitat preferences. CR = Critically Endangered; VU = Vulnerable; RA = Rare; NT = Near Threatened; LC = Least Concern; DD = Data Deficient.

Habitat preference	Species	Conservation status	Rationale used in assessment
Habitat specialist	<i>U. furcellata</i>	CR	Single microhabitat in State Park but with heavy trekker traffic
	<i>U. scandens</i>	CR	Single microhabitat in State Park with natural catastrophe (flash flood) risk
	<i>U. involvens</i>	VU	Single protected locality but affected by amenity development
	<i>U. punctata</i>	VU	Last remaining protected locality with invasive waterweed risk
	<i>U. vitellina</i>	RA	Sensitive montane species in 2 protected localities
Habitat generalist	<i>U. caerulea</i>	VU	Highland pink form in 2 protected localities; lowland white form experiencing population decreased
	<i>U. striatula</i>	NT	Fairly common in mountainous waterways but sensitive to drought
	<i>U. uliginosa</i>	NT	Fairly common in acidic swamps but always within forested areas
	<i>U. gibba</i>	LC	Fairly common in acidic open waters
Open / wayside pioneer	<i>U. aurea</i>	LC	Most common aquatic <i>Utricularia</i> in Peninsular Malaysia
	<i>U. bifida</i>	LC	Common pioneer in wayside nutrient-poor wet habitats
	<i>U. minutissima</i>	LC	Fairly common in natural and wayside nutrient-poor wet habitats
Uncertain	<i>U. subulata</i>	DD	Last collected in 1925, not rediscovered, sites developed
	<i>U. limosa</i>	DD	Single collection in 1937, site developed

Utricularia scandens (Fig. 1B) used to be recorded from a number of rocky heaths or ridges that were constantly inundated on the small isolated hill range of the Gunung Ledang State Park, Johor (Ridley 1901). Gunung Ledang is popular among local and foreign tourists and received more than 11,000 visitors annually (Suksuwan & Ong 2005). According to the description by Ridley and nature guides who trekked the hill since the 1980s (Gan & Kueh, pers. comm.), the rocky heaths originally had

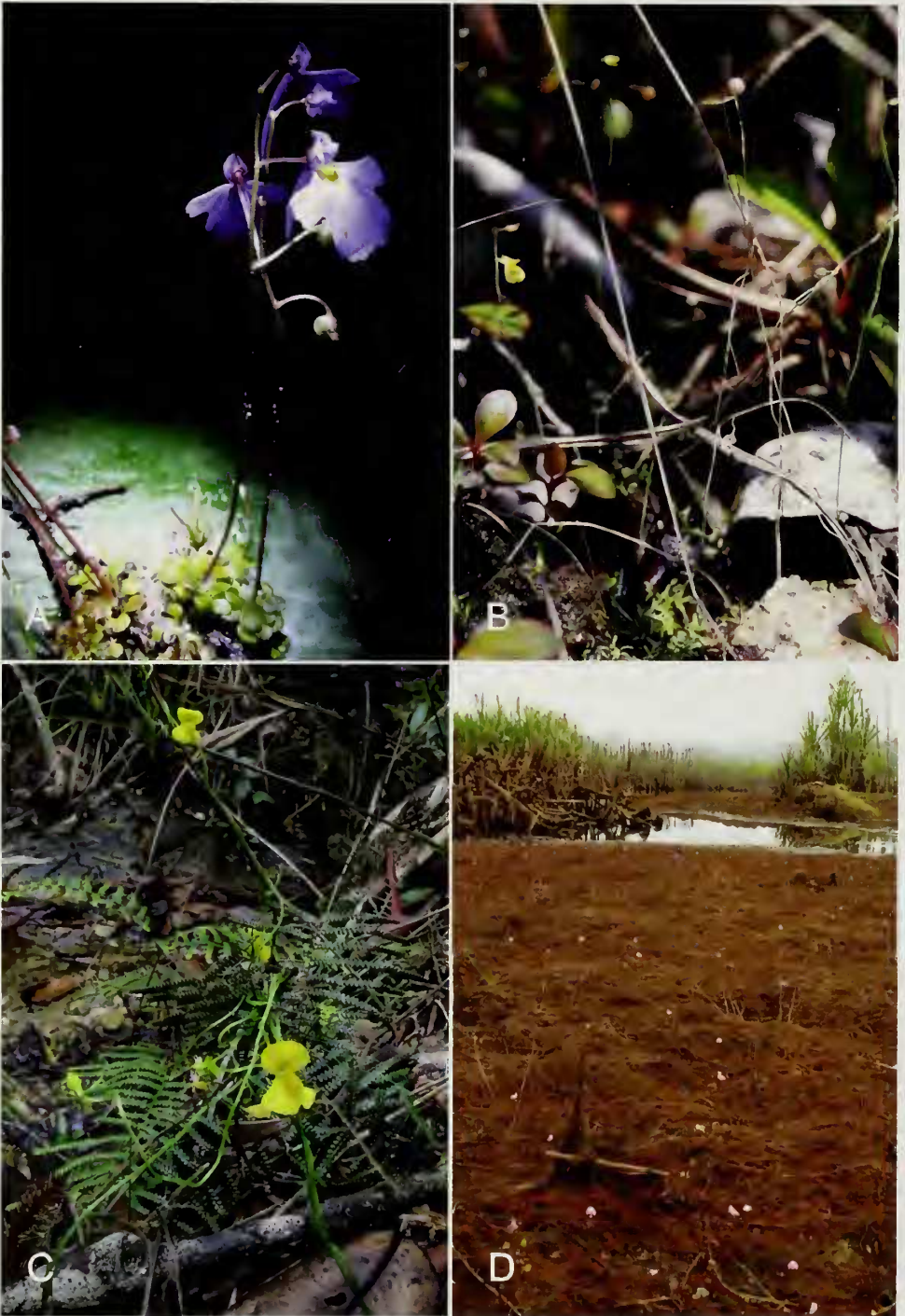


Fig. 1. Habit and habitat of four *Utricularia* species. **A.** *Utricularia firceolata* from the Gunung Ayam heath, Gunung Stong State Park. **B.** *Utricularia scandens* at Padang Batu, Gunung Mering, Gunung Ledang State Park. **C.** *Utricularia involvens* at Gunung Jerai Forest Reserve, Kedah. **D.** *Utricularia punctata* at the Tasik Bera RAMSAR site, Pahang.

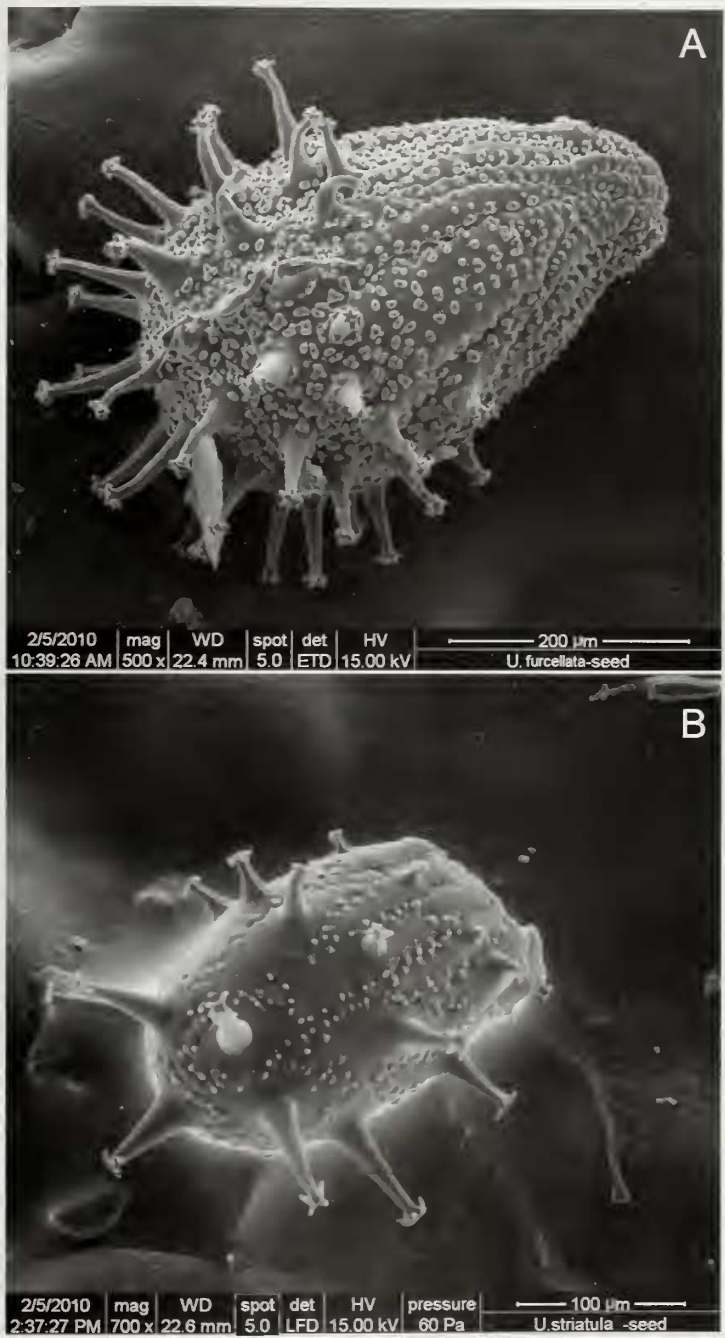


Fig. 2. Scanning electron microscopy images of *Utricularia* seeds. **A.** *Utricularia furcellata* seed showing periclinal testa cell-walls densely covered with globose or shortly clavate verrucae and the long processes that end in knobbly, clavate tips; size c. 455 μ m. **B.** *Utricularia striatula* seed showing relatively smooth periclinal testa cell-walls with verrucae occurring only along sinuate boundaries, and short processes with glochidiate, stellate tips, size c. 251 μ m.

sparse forested cover on thin soils and were constantly inundated by a thin film of seepage that flowed from the peaty, wooded ridges higher up. Much of the tracks along the rocky heath and the narrow summit ridge lost part of their vegetation cover either from the firewood cutting, campsite clearing or trees toppling over on heavily trampled soils, exposing the bedrock. Further soil erosion and loss of ground cover followed in these areas, which eventually caused the microhabitats to dry up. Parts of the trails and campsites along the waterways were littered and polluted by human waste that resulted in siltation and algal blooms in slow-flowing or stagnant waters. By the time the State Park was established in 1997 under the Johor National Parks Cooperation and stricter rules were enforced against destructive camping practices, *U. scandens* populations were depleted from all previously known collecting spots that were impacted by heavy tourist traffic. It was recently relocated from Padang Batu on Gunung Mering, a remote rocky heath above the Lampung Jatuh waterfall. The particular site was later destroyed by a rare flash flood event, further reducing the population.

Both *U. furcellata* and *U. scandens* are found in single microhabitats at one restricted site, making them highly susceptible to localised disturbance and microclimate changes. The case of *U. scandens* is a typical instance in which a sensitive species occupying an open microhabitat fringing a waterway frequented by human trekkers would inevitably disappear from the intensively utilised zones, persisting only in the more inaccessible sites. The current management practices in the two State Parks do not restrict current or future use of the sites where these sensitive species occur, hence qualifying both species 'Critically Endangered' status.

Although occurring in a variety of microhabitats, *U. involvens* (Fig. 1C) has never been found outside the Gunung Jerai Forest Reserve, Kedah. There it occurs in various open to shaded wet microhabitats. Although protected, the site is a popular tourist spot with an army camp at the summit. The species is under much pressure from amenity development and this has already led to some previously wet sites drying out. Being susceptible to local microclimate change, the conservation status of this species is scored as 'Vulnerable'.

Utricularia punctata (Fig. 1D) grows in slow-flowing, shallow open water. Habitat conversion affecting the backwaters of Sungai Pahang and Kota Tinggi, and the introduction of the noxious weed from South America, *Cabomba furcata* Schult. & Schult.f. in Roem. & Schult., that had taken over the niche of *U. punctata* in Tasik Chini, has probably wiped out the original population of the species in these places. Currently, it is surviving in Tasik Bera, Pahang—the largest freshwater lake in Peninsular Malaysia that is protected as a RAMSAR wetland site. Although locally abundant, it warrants a 'Vulnerable' status from the risk of being displaced by invasive aquatic weeds.

The sole endemic species for Peninsular Malaysia, *U. vitellina*, is found only on the two highest summits in Peninsular Malaysia, on montane peaty bryophyte mounds usually along stream banks. The highest peak, Gunung Tahan, is located within Taman Negara Pahang, while Gunung Korbu, Perak, lies within a forest reserve. Although locally abundant in the two protected sites, this species occurs only in one type of

microhabitat and is currently absent from the campsites and most parts along the trails. It is susceptible to disturbance from human activities and microclimate change, and is given a 'Rare' status.

Wet habitat generalists

Utricularia caerulea has two flower colour forms in Peninsular Malaysia. White-flowered populations are mostly lowland terrestrial plants, found in wet, sandy or muddy sites. Only two collections of plants with white flowers have been made after 1980, the others were collected from 1890 to 1964. The pink-flowered form is a terrestrial or semi-aquatic plant that grows along stream banks, and has only been recorded from Gunung Jerai and Gunung Ledang. Although the species was previously found in many sites and occupies a variety of habitats, the white-flowered form of the lowlands is becoming rare while the pink-flowered form is restricted to two sites. It is therefore given a 'Vulnerable' status.

Found on major mountain peaks and a few large waterfalls, *U. striatula* is either a minute terrestrial, lithophytic or is an epiphytic herb. *Utricularia uliginosa* is usually found in the lowlands and sometimes in the highlands. It is a stout terrestrial or semi-aquatic *Utricularia* of peat swamps, heaths and forest edges. Despite being found in many sites and able to adapt to many different microhabitats, these two 'Near Threatened' species appear to be sensitive to human disturbance and are not found outside naturally vegetated areas.

Another *Utricularia* that is rarely found away from natural habitats is *U. gibba*. The species grows in slow-flowing to stagnant waters usually bordering dryland forest or peat swamps. It sometimes colonises old man-made water bodies but has never been seen in an eutrophic lake. This species is thus given a 'Least Concern' status.

Wet habitat pioneers

Utricularia bifida and *U. minutissima* are two common terrestrial or semi-aquatic species found in open wayside wetlands and grasslands. Naturally, both are restricted to open stream banks or heath but have managed to colonise many man-made areas with fairly established vegetation and relatively stabilised soil and are often found in association with each other.

Utricularia aurea is the most common aquatic free-floating *Utricularia* found locally, usually in slow-flowing or stagnant water. Although commonly found in ditches around agriculture areas, it is not known to be weedy. Like all other *Utricularia* species, it is sensitive to all forms of fertiliser, and is noticeably absent from intensively worked paddy fields and eutrophicated old mining lakes, although it had been reported as common in these habitats by Ridley (1923) and Spare (1941).

Rare species with uncertain habitat preferences

Utricularia limosa was last recorded from low-altitude swamps in 1925 by Holttum, while *U. subulata* was last collected from Teluk Merbau, Selangor, in 1937. Repeated attempts to relocate these species from previously known sites has yielded nothing.

All the historical collection sites have been converted to built-up areas, agricultural or degraded lands. Due to a lack of information, both species are given a 'Data Deficient' status. Both species are possibly already exterminated in Peninsula Malaysia. However, because the plants of these species are so minute they could still be extant but overlooked in other wet habitats. Existing records are not specific in regard to habitat preferences and could not be verified on-site recently, leaving them with uncertain habitat preferences.

Conclusion

Utricularia is a carnivorous plant genus that grows in various wet habitats subjected to seasonal water fluxes. From field observations and growth experiments, the species are generally sensitive to changes in water nutrient content, pH, humidity, the micro-organism community and microclimate. Therefore, where they might occur, *Utricularia* species (especially those that fall within the habitat specialist group) could serve as convenient indicator species for quick assessments of the health of a habitat. The balance between habitat generalists and common pioneer species can help indicate the level of disturbance or recovery of a habitat. Conservation monitoring efforts can therefore be broadened from the species to the habitat perspective.

The initiatives of the state and federal governments of Peninsular Malaysia in setting up and managing the respective parks and reserves deserve commendation. In order to maximise the species conservation role of these protected areas while allowing recreational use, the current management practices could be further refined to cater for naturally occurring fringe species. As it stands, zonation is mostly pre-determined by accessibility or remoteness. Strict conservation zones should be re-aligned to capture different microhabitat types instead of conveniently using rivers and ridges as boundaries and assigning all the open-vegetated microhabitats as campsites. Periodic closure, especially in the wet seasons, is pivotal in preventing irreversible transformation of inundated sites and erosion in steep areas. Continuous documentation of the local flora is also essential in providing baseline information so that any degradation to the plant community that is associated with substandard amenity development or overuse can be pin-pointed.

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Appendix A. Habitat information on *Utricularia* species in Peninsular Malaysia. Notes: *No details available from specimens; information adopted from ¹Taylor (1989), ² Ridley (1923).

Species	Altitude (m)	Substrate [water pH]	Habitat notes
Section <i>Meionula</i>			
<i>U. minutissima</i>	0–2100	Wet, damp or rarely dry mud, silt, sand, laterite and shallow soil overlying rocks [4–6(–7.5)]	Exposed damp ground in lowlands and highlands; peat swamp edges; lowland heaths; highland sphagnum bog; rock faces of waterfalls or rapids; lowland river or stream banks; lowland and highland mammal trails; wayside turfs and fields; roadside seepages; constructed wetlands; recorded previously in rice fields and old mining areas
Section <i>Nigrescentes</i>			
<i>U. caerulea</i>	0–1400	Damp or wet sand, laterite, silt and shallow soil overlying rocks [4.5–6 (–7)]	Lowland and highland heaths; highland stream banks; swamps; recorded previously in wet grasslands
Section <i>Oligocista</i>			
<i>U. bifida</i>	0–1100	Wet, damp or rarely dry mud, silt, sand, laterite and shallow soil overlying rocks [4–6(–7.5)]	Exposed damp ground in lowlands and highlands; peat swamp edges; lowland heaths; lowland river or stream banks; lowland mammal trails; wayside turfs and fields; roadside seepages; constructed wetlands; recorded previously in rice fields

<i>U. involvens</i>	700–1200	Damp or wet mud and shallow soil overlying rocks [3.5–6]	Highland exposed to shaded stream banks; highland exposed to shaded wet rockfaces; wet grasslands; exposed to shaded springs and wells; wet montane road-cut outcrops
<i>U. scandens</i>	300–1000	Damp or wet sand, mud and shallow soil overlying rocks [c. 5(–6)]	Highland heath or wet grasslands on rocky heaths
<i>U. uliginosa</i>	0–1000	Seasonally flooded, damp or wet mud, peat and sand [(3–) 3.5– 6.5 (–7)]	Exposed to shaded forest edges; highland and lowland rocky stream banks; peat swamps; highland sphagnum bog; highland mammal trails; shallow pools; exposed to shaded springs and wells
<i>U. vitellina</i>	1500–2100	Damp or wet bryophyte peat mound [3.5–5]	Exposed to shaded montane mossy banks

Section *Phyllaria*

<i>U. furcellata</i>	c. 1500	Gently sloping, damp (white) sand and mud [c. 5]	Exposed heaths nestled within lower montane forest
<i>U. striatula</i>	150–2100	Damp, wet or dripping rock and tree trunk [3.5– 5.5]	Highland exposed to shaded, mossy earth banks; highland exposed to shaded wet rock faces; waterfall or rapid splash zones; tree trunks or branches within splash zones; wet montane road-cut outcrops

Section *Setiscapella*

<i>U. subulata</i> *	coastal plain	Wet or damp sand and shallow soil overlying rocks ¹ [n.a.]	Low open marshes; ditches; stream and pool sides ¹
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Section *Nelipus*

<i>U. limosa</i> *	coastal plain	Wet sand and mud ¹ [n.a.]	Open country wet spots ² ; swamps; pool margins; lowland shallow waters ¹
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Section *Utricularia*

<i>U. aurea</i>	0–1300	Often edges of still or slow flowing water, rarely wet or damp mud and silt [3–7(–7.5)]	Peat swamp edges; river backwaters; open wetlands; puddles in open fields; <i>gelam</i> swamp forests; tidal <i>typha</i> reed beds; natural or man-made lakes, ponds, reservoirs, dams and depressions; old oil palm estate, village or wayside ditches and canals; abandoned rice-field patches or organic rice-fields; ex-mining ponds; constructed wetlands; recorded previously in highland catchment pond
<i>U. gibba</i>	0–1300	Often shallow and sometimes deep, still or slow flowing water with low pH, sometimes wet or damp mud and silt [3–5.5(–7)]	Peat swamp edges; river backwaters; open wetlands; tidal <i>typha</i> reed beds; natural or man-made lakes and ponds; ditches and canals bordering peat swamps or forests; abandoned rice-field patches or organic rice-fields; constructed wetlands; tanks; recorded previously in highland catchment pond
<i>U. punctata</i>	0–250	Often edges of still or slow flowing black water with low pH, rarely wet or damp mud and silt [3–5]	Various niches at the edge of natural lakes; recorded previously in river backwaters

Appendix B. Taxonomic notes on the *Utricularia furcellata* specimen of Peninsular Malaysia. Vegetatively, *Utricularia furcellata* is very similar to *U. striatula* from the same section *Phyllaria*. They can be differentiated by the following micromorphological details.

	<i>U. furcellata</i>	<i>U. striatula</i>
Lower corolla lip	More-or-less 4-lobed, lateral lobes much smaller than the apical pair	More-or-less regularly 5-lobed
Average seed length	455 µm (N = 15)	251 µm (N = 15)
Periclinal testa cell-walls	Densely covered with globose or shortly clavate verrucae	Relatively smooth with verrucae only along the sinuate boundaries
Papillae	Densely papillate, processes long with knobbly, clavate tips	Sparsely papillate, processes short with glochidiate, stellate tips

Note: the lower corolla lip of the Kelantan specimen (*Chew et al.* FRI53603) is only shallowly lobed compared to the plants recently recorded from Northern Thailand (Suksathan & Parnell 2010), but the flower and inflorescence dimensions and descriptions match that of Taylor (1989).